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PROVISIONAL SPECIFICATION

Improvements in Brass

We, JAMES BOOTH & COMPANY (1915) LIMITED, a British Company, of Argyle Street Works, Nechells, Birmingham, 7, in the County of Warwick, and CHRISTOPHER SMITH, a British Subject, of the Company's address, do hereby declare the nature of this invention to be as follows:—

This invention relates to an improved form of high tensile brass.

The usual types of high tensile brass are of a chemical composition such that at high temperatures they are wholly or partly of Beta brass and are thus worked and fabricated at such temperatures relatively easily. After working they are generally allowed to cool in air and may be subsequently annealed. The mechanical properties possessed by such brasses depend mainly on the chemical composition and can be varied only to a small degree by variations in metallurgical procedure.

The object of the present invention is to provide a brass which is not only eminently suitable for all hot fabrication purposes such as extrusion, rolling, forging, stamping, forming or the like which may be used with high tensile brasses at present available, but is also responsive to subsequent heat treatment whereby improved mechanical properties can be obtained and varied over a wide range by suitable modification of the treatment details.

According to the present invention we provide a brass containing copper and zinc as principal constituents with magnesium from 0.2 to 3.0%, up to 3% of the copper or zinc contents, or both, being replaceable by other elements and the copper content (or the total content of copper plus the proportion thereof replaced by other elements) being within the Alpha-Beta brass range (i.e. 55 to 65%).

The copper may contain certain other metals up to 3% of the whole to improve its machinability or other properties and these metals may be nickel, manganese, iron or lead, or any two or more of these.

The zinc may contain up to 3% of certain other elements and these may be silicon, aluminium or tin or any two or more of these.

The magnesium content varies in accordance with the amount of copper in the brass, i.e. the magnesium content will be towards the lower end of the magnesium range for brasses having the copper content near the lower end of the copper range.

The magnesium content may, for instance, vary approximately in accordance with the following table:—

Cu.%	Mg.% Range	Zinc
58.0	0.2—2.5	Remainder
59.0	0.2—2.5	,,
60.0	0.2—2.5	,,
61.0	0.2—2.5	,,
62.0	0.2—3.0	,,
63.0	1.0—3.0	,,
64.0	2.0—3.0	,,

The alloy may be made in the first instance by adding zinc to molten copper and then adding to the mixture a hardening alloy of zinc magnesium. The mixture is then allowed to solidify to form the improved brass.

The improved brass may be subjected to heat treatment by heating it to produce a Beta matrix and quenching with or without hot working by rolling, forging, extrusion or otherwise, before quenching, re-heating the quenched brass to a temperature from room temperature up to approximately 500°C. for a period of from five minutes to five hours and then allowing it to cool.

The first heating of the brass in the heat treatment may be carried up to approximately 850°C. but is normally about 750°C.

The brass forming the subject of the present invention when heated to a suitable high temperature, say 750°C. is composed wholly or in part of Beta brass and is easily worked. If the magnesium content is towards the upper limit, the brass may also contain appreciable amounts of an intermetallic compound of copper, magnesium and zinc.

After being heated as described, the brass may be quenched, for example in water, and its internal structure is then retained at room temperature.

If hot working is carried out, the

quenching may take place immediately after working. We prefer, however, to allow the brass to cool normally after hot working and to re-heat it to the correct temperature before quenching.

After quenching, the brass is capable of sustaining, assuming that the magnesium content is not too high, all the light fabrication that is commonly used for a normal Beta brass.

The second part of the heat treatment consists in re-heating the quenched material to a temperature between 20°C. and 500°C. for a period which may vary from five minutes to five hours, and then allowing it to cool.

When this second part of the heat treatment is carried out, the Beta structure breaks down towards the equilibrium structure of Alpha or Alpha plus some Beta, at the same time developing a finely dispersed precipitate of the intermetallic compound of copper, magnesium and zinc.

The maximum hardness attainable by this treatment occurs when the re-heating is carried to about 250°C. and such hardness may reach over 300 Vickers Pyramid Numeral. When higher temperatures are used they produce decreases in hardness as the temperature is raised, with corresponding changes in the tensile properties.

After the second part of the heat treatment, the matrix is no longer Beta but becomes substantially Alpha brass, and it is then much less susceptible to intercrystalline cracking than is Beta brass. This can be shown by its behaviour in mercury, molten solders and certain corrosive solutions.

Two examples of brass constructed in accordance with this invention will now be given, together with the results of mechanical tests in various conditions of heat treatment after extrusion as a one-inch diameter bar:—

BRASS No. 1. Composition: Copper 60.7%
Magnesium 1.01%
Zinc remainder

	0.1% Proof stress. tons/in².	Maximum strength. tons/in².	Elongation % on 2″	Hardness Vickers Pyramid Numeral
As extruded	10	26.5	30	106
Water quenched 750°C.	25	35	5	155
,, ,, ,, reheated 1 hr. 300°C.	39.5	47	2.5	230
,, ,, ,, ,, 350°C.	36	43	4	195
,, ,, ,, ,, 400°C.	29	40	15	170
,, ,, ,, ,, 450°C.	25	36.5	19	155
Annealed 650°C.	9.5	26	33	108

BRASS No. 2. Composition: Copper 61.2%
Magnesium 0.67%
Zinc remainder

	0.1% Proof stress. tons/in².	Maximum strength. tons/in².	Elongation % on 2″	Hardness Vickers Pyramid Numeral
As extruded	9.5	27	31	97
Water quenched 750°C.	23	37	9	137
,, ,, ,, reheated 1 hr. 300°C.	24	38	9	165
,, ,, ,, ,, 400°C.	19	34	22	130

It will be seen that very high values are obtained for the proof stresses.

Fatigue tests in rotary bending carried out on these two brasses, water quenched from 750°C. and reheated for one hour at 400°C. gave fatigue strengths at 50 million cycles of ± 13.6 tons/in.² and ± 11.9 tons/in.² respectively.

In the two examples set out, the brass is subjected to hot working. Hot working may be omitted, in which case the brass is used in the cast condition and can be given the same heat treatment as that already described with similar metallurgical reactions.

The brass constructed in accordance with this invention possesses good machining properties and, being free from aluminium, or substantially so, is readily soldered.

Dated the 19th day of March, 1943.
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COMPLETE SPECIFICATION

Improvements in Brass

We, JAMES BOOTH & COMPANY LIMITED, formerly known as James Booth & Company (1915) Limited, a British Company, of Argyle Street Works, Nechells, Birmingham, 7, in the County of Warwick, and CHRISTOPHER SMITH, a British Subject, of the Company's address, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to an improved form of high tensile brass, and is concerned with Alpha-Beta brasses.

The usual types of high tensile brass are of a chemical composition such that at high temperatures they are wholly or partly Beta brass and are thus worked and fabricated at such temperatures relatively easily. After working they are generally allowed to cool in air and may be subsequently annealed. The mechanical properties possessed by such brasses depend mainly on the chemical composition and can be varied only to a small degree by variations in metallurgical procedure.

The object of the present invention is to provide a brass which is not only eminently suitable for all hot fabrication purposes such as extrusion, rolling, forging, stamping, forming or the like which may be used with high tensile brasses at present available, but is also responsive to subsequent heat treatment whereby improved mechanical properties can be obtained and varied over a wide range by suitable modification of the treatment details.

Our invention consists primarily in the addition to an Alpha-Beta brass of the element magnesium within the range of 0.3 to 2.5%.

As distinct from Alpha-Beta brasses which do not contain magnesium, the mechanical properties of a brass in accordance with the present invention may be considerably enhanced by suitable heat treatment, described hereinafter more fully with reference to certain specific examples, but which heat treatment shortly consists in quenching the brass from a suitable high temperature, say 750°C., at which temperature the brass is composed wholly or mainly of Beta brass, and consequently is easily worked.

The magnesium is largely or completely dissolved in the Beta matrix, although if the magnesium content is towards the upper limit above specified, it is believed that some of the magnesium is present as an inter-metallic compound with the copper and zinc, which latter form the principal constituents of the brass. The above internal structure is retained at room temperature after quenching.

If the quenched material is now reheated to a temperature, and for a period, dependent upon the composition of the brass, the Beta structure breaks down and the matrix becomes wholly Alpha brass, or mainly Alpha brass plus some Beta brass, and as magnesium is only slightly soluble in Alpha brass at the temperatures in question, it is believed to be substantially all precipitated as a finely dispersed precipitate of the inter-metallic compound of copper, magnesium and zinc. This compound is hard, and it is believed that to its presence are due the improved mechanical properties obtainable from a brass in accordance with the present invention, as will become hereinafter apparent.

If desired, a part of the copper content may be replaced by one or both of the elements nickel and manganese; and a part of the zinc content may be replaced by one or more of the elements lead, iron, silicon, aluminium and tin, and in a more specific form this composition may be defined as an Alpha-Beta brass containing copper and zinc as principal constituents, magnesium from 0.3 to 2.5%, and one or more of the additional elements nickel, manganese, iron, lead, tin, aluminium, silicon, the total amount of said additional elements in all not exceeding 3%, with the aluminium or silicon content, where these elements are present, not exceeding 2% and 1% respectively, the percentage of copper being 56 to 63% in the absence of said additional elements, or in the presence only of the additional elements iron, lead, but being varied in accordance with the following table where the additional elements comprise nickel, manganese, tin. aluminium, silicon, the copper ranges for the intermediate percentages of these elements being calculated proportionally:—

Additional Element.	1% element. % Cu.	2% element. % Cu.	3% element. % Cu.
Nickel - - - - - -	54.8—61.6	53.6—60.1	52.3—58.8
Manganese - - - - -	55.7—62.6	55.4—62.3	55.2—62.0
Tin - - - - - - -	56.8—63.6	57.3—64.2	57.8—64.8
Aluminium - - - - -	59.0—66.1	61.7—69.3	— —
Silicon - - - - - -	61.1—68.6	— —	— —

the remainder of the composition being zinc plus the usual impurities normally present in commercial Alpha-Beta brass.

The lead or iron content, where these elements are present, should not exceed 2% and 1% respectively.

In the case of a straight ternary alloy where the brass does not contain any of the said additional elements, it is preferred that the minimum magnesium content shall not be less than 0.5%, which minimum content varies slightly with the copper content, although the maximum magnesium content remains substantially constant throughout the copper range, and as applied to a straight ternary alloy we provide a brass containing copper 56—63%, magnesium within the following range according to the copper content:—

Cu%	Mg%
56 - - - - - -	0.9—2.5
57 - - - - - -	0.8—2.5
58 - - - - - -	0.7—2.5
59 - - - - - -	0.6—2.5
60 - - - - - -	0.5—2.5
61 - - - - - -	0.5—2.5
62 - - - - - -	0.5—2.5
63 - - - - - -	0.5—2.5

the balance being zinc and the usual impurities normally present in commercial Alpha-Beta brass. The presence of one or more of the said additional elements lowers the preferred minimum range of the magnesium.

A preferred brass in accordance with our invention has the following composition:—

Copper 59—61%
Magnesium 0.9—1.2%
Zinc and the usual impurities normally present in commercial Alpha-Beta brass—the remainder.

Our invention resides also in a method of heat treating a brass having any of the above compositions which comprises quenching the brass from a temperature above that at which it becomes substantially Beta in structure and below its melting point either immediately after hot working at or an initial reheating to such temperature range, reheating the quenched metal to a temperature (not exceeding 500°C.) and for a period, sufficient to break down the Beta structure to Alpha or Alpha plus some Beta, and then allowing the brass to cool.

The temperature of reheating is dependent upon the composition of the brass. For the preferred composition it is 200—500°C. for a period of 30 minutes to five hours, the temperature and time varying in accordance with the degree of hardness ultimately desired.

The pressure of certain of the additional elements aforesaid may make such reheating unnecessary. For example, brasses containing iron are found to be fully hardened as quenched and without further heat treatment, the Beta structure in such cases having broken down during the quenching operation.

The brass in accordance with the present invention is preferably made by adding zinc to molten copper and then adding to the mixture the magnesium either as magnesium metal or as a master alloy with copper or zinc. Where the said additional elements are present they are added to the molten copper either as the pure elements, or as master alloys with copper or zinc, and said addition to the copper is made before the zinc is added. The mixture is then cast in the known manner.

Alternatively, the brass may be made by any other known method for manufacturing Alpha-Beta brass, for example by a powder method.

The brass is then subjected to heat treatment by heating it to a temperature sufficiently high to produce a substantially Beta matrix, which temperature is in general within the range of 700°C. to the temperature at which the brass commences to melt, according to the composition of the brass, and for the preferred composition above specified, is between 700 and 850°C. preferably between 700 and 750°C. The brass is then quenched in water or oil, prior to which it may be hot worked as desired, e.g. by rolling, forging or extrusion, although where hot working is carried out it is preferred to allow the brass first to cool normally and then to reheat it to the correct temperature before quenching.

The internal Beta structure, except in the case of certain brasses containing additional elements, is normally retained on quenching so that the brass is wholly or mainly in the Beta form and conse-

quently is capable of the light fabrication that is conveniently used in a normal Beta brass.

When reheating is necessary to break down the Beta structure, this is carried out at a temperature not exceeding 500°C. and for a period which may vary from 5 minutes to 5 hours, after which the brass is allowed to cool, and owing, it is believed, to the development above referred to of the finely dispersed precipitate of the copper, magnesium, zinc, inter-metallic compound, a very considerable improvement in the mechanical properties of the brass now results.

The maximum hardness attainable by this treatment occurs when the reheating is carried to about 250°C. and such hardness may reach over 300 Vickers Pyramid Numeral. When higher temperatures are used they produce decreases in hardness as the temperature is raised, with corresponding changes in the tensile properties.

After the final stage of the heat treatment, owing to the fact that the matrix is now wholly or mainly Alpha, it is much less susceptible to inter-crystalline cracking than is the case with a Beta matrix. This can be shown by its behaviour in mercury, molten solders and certain corrosive solutions.

The brass may be subjected to cold deformation either in the fully annealed condition (slowly cooled from about 650°C.) or as fully heat-treated when the final stage of the treatment was carried out at 400°C.—450°C. In the latter case the hardening effects of cold work may be removed by further treatment at 400°C—450°C. without causing distortion.

Examples of brass made in accordance with the invention will now be given together with the results of mechanical tests in various conditions of heat treatmen. The form and composition of the brass is stated in each case.

Brass No. 1. Copper - - - - - - 60.7%
Magnesium - - - - 1.01%
Zinc - - - - - - - remainder.

One inch diameter extruded bar.

	0.1% Proof stress. tons/in².	Maximum strength. tons/in².	Elongation % on 2″	Hardness Vickers Pyramid Numeral
As extruded	10	26.5	30	106
Water quenched from 750°C.	25	35	5	155
and reheated 1 hr. 300°C.	39.5	47	2.5	230
,, ,, ,, ,, 350°C.	36	43	4	195
,, ,, ,, ,, 400°C.	29	40	15	170
,, ,, ,, ,, 450°C.	25	36.5	19	155
Annealed 650°C.	9.5	26	33	108

Brass No. 2. Copper - - - - - - 61.2%
Magnesium - - - - 0.67%
Zinc - - - - - - - remainder.

One inch diameter extruded bar.

	0.1% Proof stress. tons/in².	Maximum strength. tons/in².	Elongation % on 2″	Hardness Vickers Pyramid Numeral
As extruded	9.5	27	31	97
Water quenched from 750°C.	23	37	9	137
and reheated 1 hr. 300°C.	24	38	9	165
,, ,, ,, ,, 400°C.	19	34	22	130

Brass No. 3. Copper - - - - - - 60.3%
Magnesium - - - - 0.76%
Zinc - - - - - - - remainder.

$\frac{1}{8}$″ thick extruded strip.

	0.1% Proof stress. tons/in².	Maximum strength. tons/in².	Elongation % on 2″	Hardness Vickers Pyramid Numeral
Oil quenched from 750°	20.9	36	16.5	147
and reheated 1 hr. 250°C.	42 apprx.	42	2	205
,, ,, ,, ,, 350°C.	25.6	40.8	10.5	164

BRASS No. 4.

Copper - - - - - 61.2%
Magnesium - - - - 1.74%
Zinc - - - - - - - remainder.

⅛" thick extruded strip.

	0.1% Proof stress. tons/in².	Maximum strength. tons/in².	Elongation % on 2"	Hardness Vickers Pyramid Numeral
Oil quenched from 730°C. and reheated 1 hr. 350°C.	32.3	37	18	—

BRASS No. 5.

Copper - - - - - 59.3%
Magnesium - - - - 1.0%
Zinc - - - - - - - remainder.

2½" extruded bar.

	0.1% Proof stress. tons/in².	Maximum strength. tons/in².	Elongation % on 2"	Hardness Vickers Pyramid Numeral
Water quenched from 710°C. and reheated 1 hr. 400°C.	25.4	37.2	20	189

BRASS No. 6.

Copper - - - - - 59.4%
Magnesium - - - - 0.92%
Manganese - - - - 1.04%
Zinc - - - - - - - remainder.

¾" diameter forged bar.

	0.1% Proof stress. tons/in².	Maximum strength. tons/in².	Elongation % on 2"	Hardness Vickers Pyramid Numeral
Water quenched from 710°C. and reheated 1 hr. 400°C.	27.8	41.2	8	183
,, ,, ,, ,, ¾ hr. 450°C.	22.8	37.5	18	172

BRASS No. 7.

Copper - - - - - 60.2%
Magnesium - - - - 1.03%
Tin - - - - - - - 0.49%
Zinc - - - - - - - remainder.

¾" diameter forged bar.

	0.1% Proof stress. tons/in².	Maximum strength. tons/in².	Elongation % on 2"	Hardness Vickers Pyramid Numeral
Water quenched from 800°C. and reheated 1 hr. 300°C.	27.6	39.2	13.5	170

BRASS No. 8.

Copper - - - - - 64%
Magnesium - - - - 1.26%
Aluminium - - - - 0.99%
Zinc - - - - - - - remainder.

¾" diameter forged bar.

	0.1% Proof stress. tons/in².	Maximum strength. tons/in².	Elongation % on 2"	Hardness Vickers Pyramid Numeral
Water quenched from 700°C. and reheated 1 hr. 400°C.	35.6	42.4	4	206

BRASS No. 9.

Copper - - - - - 60.5%
Magnesium - - - - 1.24%
Iron - - - - - - - 0.74%
Zinc - - - - - - - remainder.

	0.1% Proof stress. tons/in².	Maximum strength. tons/in².	Elongation % on 2″	Hardness Vickers Pyramid Numeral
Water quenched from 750°C. No reheating.	25.4	42.8	3	200

It will be seen that very high values are obtained for the proof stresses.

Fatigue tests in rotary bending carried out on Brasses Nos. 1 and 2 water quenched from 750°C. and reheated for one hour at 400°C. gave fatigue strengths at 50 million cycles of ± 13.6 tons/in.² and ± 11.9 tons/in.² respectively.

In the two examples set out, the brass is subjected to hot working. Hot working may be omitted, in which case the brass is used in the cast condition and can be given the same heat treatmnet as that already described with similar metallurgical reactions.

Where hot working is omitted and the brass is used in the cast condition, owing to the fact that its structure is then coarser it requires to be reheated for a longer period to break down the large, relatively coarse particles of Alpha brass into the Beta form as well as to dissolve the magnesium in the Beta matrix.

The brass made in accordance with this invention possesses good machining properties and, when free from aluminium, or substantially so, is readily soldered.

The presence of lead (up to 2%) further improves the machinability of the brass.

We are aware that it has previously been proposed, in connection with a copper-base alloy containing 0.1 to 50% zinc and 0.01 to 1% boron, to replace equivalent quantities of copper and for zinc by one or more other metals, including magnesium up to 5%, manganese up to 10%, iron up to 5%, lead up to 10%, and aluminium up to 10%, the sum of such added elements preferably not exceeding 50% of the alloy.

Another prior proposal of which we are aware concerns a copper-base alloy containing zinc up to 45%, 0.1 to 20% tin, and 0.01 to 1% boron, in which equivalent quantities of copper and tin may be replaced by one or more other elements, including magnesium up to 3%, manganese up to 10%, iron up to 10%, and lead up to 5%, the sum of such elements in addition to the copper totalling not more than 50% and at least part of the boron being in solution with the tin in the copper.

Yet another prior proposal of which we are aware has reference to a white inoxidisable alloy containing 25 to 90% copper, 0.5 to 50% nickel, 0.05 to 10% aluminium, 0.05 to 50% zinc, 0.01 to 10% iron, 0.01 to 10% silicon, and 0.01 to 5% magnesium.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. An Alpha-Beta brass containing as an additional constituent magnesium within the range of 0.3 to 2.5%.

2. An Alpha-Beta brass containing copper and zinc as principal constituents and magnesium from 0.3 to 2.5%, with one or more of the additional elements nickel, manganese, iron, lead, tin, aluminium, silicon, the total amount of said additional elements in all not exceeding 3% (with the aluminium or silicon content, where these elements are present, not exceeding 2% and 1% respectively), and the percentage of copper being 56 to 63% in the absence of said additional elements, or in the presence only of the additional elements iron, lead, but being varied in accordance with the following table where the additional elements comprise nickel, manganese, tin, aluminium, silicon, the copper ranges for intermediate percentages of these elements being calculated proportionally:—

Additional element.	1% element. % Cu.	2% element. % Cu.	3% element. % Cu.
Nickel	54.8—61.6	53.6—60.1	52.3—58.8
Manganese	55.7—62.6	55.4—62.3	55.2—62.0
Tin	56.8—63.6	57.3—64.2	57.8—64.8
Aluminium	59.0—66.1	61.7—69.3	— —
Silicon	61.1—68.6	— —	— —

the remainder of the composition being zinc plus the usual impurities normally present in commercial Alpha-Beta brass.

3. An Alpha-Beta brass containing copper 56—63%, magnesium within the

following range according to the copper content as follows:—

Cu%		Mg%
56	- - - - - -	0.9—2.5
57	- - - - - -	0.8—2.5
58	- - - - - -	0.7—2.5
59	- - - - - -	0.6—2.5
60	- - - - - -	0.5—2.5
61	- - - - - -	0.5—2.5
62	- - - - - -	0.5—2.5
63	- - - - - -	0.5—2.5

the balance being zinc and the usual impurities normally present in commercial Alpha-Beta brass.

4. A brass according to Claim 3 having the following composition:—

Copper 59—61%
Magnesium 0.9—1.2%

zinc, and the usual impurities normally present in commercial Alpha-Beta brass, the remainder.

5. A method of heat treating a brass in accordance with any of Claims 1 to 4, which comprises quenching the brass from a temperature above that at which it becomes substantially Beta in structure and below its melting point either immediately after hot working at or an initial reheating to such temperature, such quenching (with or without reheating to a temperature, and for a period, dependant upon the specific composition of the brass and the degree of hardness desired, such temperature not exceeding 500°C.) having the effect of breaking down the Beta structure to Alpha or Alpha plus some Beta.

6. A method according to Claim 5 for heat treating the specific brass claimed in Claim 4, which comprises quenching the brass from a temperature of 700 to 850°C. either immediately after hot working at or an initial reheating to such temperature, then reheating the quenched brass to a temperature of 200 to 500°C. for a period between 30 minutes and five hours, and finally allowing the reheated brass to cool.

7. A method according to Claim 6, wherein the brass is water quenched from a temperature of 700 to 750°C. and is reheated to a temperature of 400—450°C. for a period of one hour.

8. A method according to any of Claims 5 to 7 wherein the brass is hot worked after casting, e.g. rolled, forged, or extruded before subjecting it to the heat treatment.

9. A brass according to any of Claims 1 to 4 and heat treated by the method set forth in any of Claims 5 to 8.

10. A heat treated brass substantially as set forth in Examples Nos. 1 or 5.

11. A heat treated brass substantially as set forth in Examples Nos. 2 or 3.

12. A heat treated brass substantially as set forth in Example No. 4.

13. A heat treated brass substantially as set forth in any of Examples Nos. 6, 7 or 8.

14. A heat treated brass substantially as set forth in Example No. 9.

Dated this 22nd day of January, 1944.
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